REMARKS / ARGUMENTS

In the above-identified Office Action the Examiner has rejected claims 5-7 and 10 as unpatentable over Toeda in view of Ikari et al.

The Examiner has concluded that it would have been obvious to use a nitrogen doped semiconductor substrate as taught by Ikari et al. in the structure of Toeda to improve the gettering ability of the substrate. Applicant disagrees with this rationale, noting that the subject claims recite plural epitaxial layers and not just one as in Ikari et al. and Toeda. Further, in Applicant's invention the plural epitaxial layers are stacked on a front side of the semiconductor substrate. The Examiner has interpreted front side to mean upper surface when, in fact, it is not. The mirrors are stacked on only a portion of the semiconductor substrate, front as opposed to the rear of this substrate (on the same upper side of the substrate). The shape of construction has different effects from different sides as set forth in lines 5-11, page 3 of the specification, as well as elsewhere. Thus, neither Toeda nor Ikari et al. teach the same structure even if these two references were to be combined, and would not yield the subject invention.

In addition, and as will be explained below, Applicant's invention has improved over the present by improving the gettering capacity by lowering/shortening the heat treatment temperature/time and by making the epitaxial layer thinner.

The attached Fig.1 depicts a test result showing a relationship between the film thickness and the gettering capacity of a first epitaxial layer. In this test, a wafer having a first epitaxial layer 3 and a second epitaxial layer 4 stacked on a silicon substrate 2 is purposely contaminated with Fe and heat-treated, and thereafter, Fe concentration of the second epitaxial layer 4 is measured (DLTS method) (the reference numerals used here are of Fig.1 of the instant application). Respective conditions are as follows:

- First epitaxial layer 3

  Resistivity 100/1000 Ω·cm, Film thickness 1 μm, 5 μm, 30 μm

  Resistivity 50/1000 Ω·cm Film thickness 1 μm, 5 μm, 30 μm

  Resistivity 15/1000 Ω·cm Film thickness 1 μm, 2 μm, 5 μm, 10 μm, 30 μm

- Second epitaxial layer 4

  Resistivity 10 Ω·cm Film thickness 5 μm

- Silicon substrate

  Resistivity 20 Ω·cm Not doped with nitrogen

- Heat treatment temperature/time

  780°C/3Hr + 1000°C/16Hr

- Contamination concentration

  2E13/cm^2 of Fe contamination on the surface of second epitaxial layer 4

Referring to the attached Fig. 1, it is noted that the lower resistivity of the first epitaxial layer, i.e., the higher the impurity concentration, the more gettering capacity increases. Further, the thicker the first epitaxial layer is the more the gettering capacity increases. In other words, if the resistivity of the first epitaxial layer is lowered, i.e., if the impurity concentration is higher, the gettering capacity can be increased, even if the film thickness of the first epitaxial layer is made thinner.

The attached Fig.2 depicts the test result shown in Fig.1, a test result of the case where the heat treatment temperature/time are lowered/shortened. Heat treatment temperature/time are as follows.

Heat treatment temperature/time

750°C/2Hr + 980°C/1.5Hr

Referring to Fig.2, it is noted that the gettering capacity is inferior to that of the epitaxial wafer used in the test shown in Fig.1. However, it is understood that, if the resistivity of the first epitaxial layer is lowered, i.e., if the impurity concentration is made high, the gettering capacity can be increased even if the heat treatment temperature/time are lowered/shortened.

(3)The attached Fig.3 depicts a test result showing the gettering capacity of the epitaxial wafer in which the impurity concentration of the first epitaxial layer is increased

and the silicon substrate is nitrogen-doped. In this test, as similar to the above, the epitaxial wafer having the first epitaxial layer 3 and the second epitaxial layer 4 stacked on the silicon substrate 2 is purposely contaminated with Fe and heat-treated, thereafter. Fe concentration of the second epitaxial layer 4 is measured (DLTS method). Respective conditions are as follows.

- First epitaxial layer 3

  Resistivity 50/1000Ω·cm, Film thickness 5 μm, (same with (1) and part of (2))
- Second epitaxial layer 4

  Resistivity 10Ω·cm, Film thickness 5 μm, (same with (1) and (2))
- Silicon substrate

  Resistivity 10Ω·cm, With BMD formed by nitrogen doping
- Heat treatment temperature/time

  750°C/2Hr + 980°C/1.5Hr(same with (2))
- Contamination concentration

  2E13/cm^2 of Fe contamination on the surface of second epitaxial layer 4 (same with (1) and (2)).

In the attached Fig.3, the test results of the epitaxial wafer (P/P- with IG) having only bulk micro defects (BMD)is also shown in order to compare with the test result of the epitaxial wafer (P/P+/P- with IG) is higher than that of the epitaxial wafer (P/P- with IG). That is, the gettering capacity of the epitaxial wafer is further improved by improving the gettering capacity of the first epitaxial layer by increasing the impurity concentration of the first epitaxial layer, and by improving the gettering capacity of the silicon substrate by doping with nitrogen to form BMD. Furthermore, the gettering capacity is improved compared to that of the epitaxial wafers of the same impurity concentration and the same film thickness shown in the attached FIGs. 1 and 2.

Thus, both of the first epitaxial layer and the silicon substrate can getter Fe and Cu. The gettering capacity is improved compared to that of the first epitaxial layer itself of that of the silicon substrate itself.

As discussed above, according to the instant invention, both of the first epitaxial layer and the silicon substrate have gettering capacity. For this reason, degradation in the gettering capacity of the first epitaxial layer can be accepted and the first epitaxial layer can be thinner or the heat treatment temperature/time can be lowered/shortened. As a result, epitaxial wafer manufacturing efficiency can be improved.

Defect getters such as BMD, etc. cannot be formed beyond the solid-solution limit. For this reason, the gettering capacity has its limit. On the other hand, the gettering capacity of the epitaxial layer with plural layers stacked thereon, as in the instant invention, is determined by the impurity concentration ration of the epitaxial layer irrespective of the solid-solution limit. The inventors of the instant invention believe that the above-mentioned advantageous effect (1) can be achieved when two getter sources exist in different locations (the silicon substrate and the first epitaxial layer) as in the instant invention.

For instance, assume that BMD is formed in the first epitaxial layer. In this case, two getter sources coexist in the first epitaxial layer; however, since BMD is not formed beyond the solid-solution limit, only one of the getter sources (impurity: Boron etc.) functions, and the other one of the getter sources (BMD) does not function. This is not the case if BMD is formed in the silicon substrate.

Because Ni is not easily ionized in the silicon substrate, it is not easy to getter NI in the first epitaxial layer, which, however is gettered by BMD in the silicon substrate.

The attached FIG.4 depicts the lifetime of the epitaxial wafer of the instant invention that is contaminated with Ni. Referring to the attached FIG.4, it is noted that the lifetime of the epitaxial wafer does not change by the NI contamination.

Meantime, since Fe and Cu can be ionized (+), they are gettered by the first epitaxial layer. Therefore, the epitaxial wafer of the instant invention can efficiently getter not only Fe and Cu, but also the Ni that is difficult to be gettered by the first

epitaxial layer. Thus, the epitaxial wafer of the instant invention is capable of gettering many contamination elements.

It is with the structure of the subject invention as claimed that Applicant can realize all of the above noted benefits, which cannot be realized through the combination of Ikari et al. and Toeda.

Applicant hereby requests reconsideration and reexamination thereof.

No further fee or petition is believed to be necessary. However, should any further fee be needed, please charge our Deposit Account No. 23-0920, and deem this paper to be the required petition.

With the above amendments and remarks, this application is considered ready for allowance and applicant earnestly solicits an early notice of same. Should the Examiner be of the opinion that a telephone conference would expedite prosecution of the subject application, he/she is respectfully requested to call the undersigned at the below listed number.

Respectfully submitted,

Gerald T. Shekleton

Dated:

Gerald T Shekleton
Reg. No. 27,466
Husch Blackwell Sanders Welsh & Katz
120 South Riverside Plaza, 22nd Floor
Chicago, Illinois 60606
Phone: (312) 655-1511
Fax: (312) 655-1501